



ESTONIAN UNIVERSITY OF LIFE SCIENCE

Faculty of Veterinary Medicine

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**EFFECT OF FINNISH SAUNA TO EQUINE MUSCLE TONE  
BASED ON MYOTONPRO MEASUREMENTS**

**SAUNATAMISE MÕJU HOBUSTE LIHASTOONUSELE  
MYOTONPRO MÕÕTETULEMUSTE ALUSEL**

Final Thesis in Veterinary Medicine

Curriculum in Veterinary Medicine

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## LIST OF ABBREVIATIONS

1RM - one repetition maximum

*et al.* – *et alii* (and others)

Fig. - Figure

FMD - Flow-mediated vasodilation

Hz - hertz

*M.* – *musculus* (muscle)

Nm – Newton metre

P - page

# ABSTRACT

Estonian University of Life Sciences Kreutzwaldi 1, Tartu 51014		Abstract of Veterinary Medicine Study Thesis	
Author: Maija Talvikki Vesterinen		Specialty: Veterinary Medicine	
Effect of Finnish sauna to equine muscle tone based on MyotonPRO measurements			
Pages: 34	Figures: 11	Tables: 2	Appendixes: 1
Chair: Chair of clinical veterinary medicine Research classification: B710 Physical medicine, kinesitherapy, revalidation, rehabilitation Supervisors: Reet Herm, Arvo Viltrop Place and date: Tartu 2018			
Sauna bathing is a popular and familiar habit among humans. Some horse trainers take sport horses to sauna because it is believed to speed up post-training recovery. Sauna bathing within horses has not been studied before. The aim of this study was to see whether sauna bathing has effects on horses' muscle tone and stiffness. Temperature in sauna was 50 to 60 °C and relative humidity 80 to 100 % and horses spent there approximately 42 minutes in two phases. A myotonometric device called MyotonPRO was used to measure 3 different muscles during and after sauna bathing. Results were statistically analyzed and compared with control group. Sauna effect to muscle tone or stiffness was not detected during this study. It was found that test group had lower tone and stiffness in <i>longis thoracis</i> compared with control group. Sauna bathing caused tachycardia and tachypnoea in all test horses, but its meaning would need further research. Hematological and biochemical profiles would need further research.			
Keywords: sauna, muscle, myotonometric			

# LÜHIKOKKUVÕTE

Eesti Maaülikool Kreutzwaldi 1, Tartu 51014		Loomaarstiõppe lõputöö lühikokkuvõte	
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Saunatamise mõju hobuste lihastoonusele MyotonPRO mõõtetulemuste alusel			
Lehekülgi: 34	Jooniseid: 11	Tabeleid: 2	Lisasid: 1
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Saunas käimine on populaarne ja harilik traditsioon inimeste hulgas. Mõned hobusetreenerid viivad ka hobuseid sauna, sest arvatakse, et saunatamine kiirendaks hobuste trennist taastumist. Hobuste saunas käimise tagajärgi pole varem uuritud. Selle töö eesmärk oli uurida, kas saunatamisel on mõju hobuste lihastoonusele. Sauna temperatuur oli uuringu käigus 50 kuni 60 °C ja suhteline niiskus 80 kuni 100 % ja hobune veetis seal keskmiselt 42 minutit kahefaasiliselt. Uuringus kasutati MyotonPRO nimelist seadet, millega mõõdeti saunas käimise käigus 3 erinevat lihast. Tulemusi analüüsiti statistiliselt ja võrreldi kontrollgrupiga. Uuringu käigus ei leitud saunatamise mõju lihastoonusele. Testgrupi hobustel märgati väiksemat toonust ja jäikust <i>longis thoracis</i> lihases võrreldes kontrollgrupiga. Saunas oleku ajal märgati kõikidel testhobustel tahhükardiat ning tahhüпноet, mille tähendus vajaks edasist uurimist. Edasised uuringud hematoloogiliste ja biokeemiliste muutuste tuvastamiseks oleksid vajalikud.			
Märksõnad: sauna, lihas, müotonomeetria			

# INTRODUCTION

Finnish people and sauna is an inseparable combination. Finland has approximately 2 million official saunas which is 0.4 saunas per each Finnish inhabitant. This habit is estimated to be over 2000 years old and it still brings people together. (Suomi nyt, 2018) Sauna bathing has been proven to improve cardiac function (Sobajima *et al.* 2015), reduce blood pressure (Laukkanen *et al.* 2018) and reduce the risk of getting pulmonary diseases (Kunutsor *et al.* 2017).

Taking horses to sauna is an old custom in Finland and has been practiced for decades. Historically horses were taken to sauna to improve their hygiene and to take care of them (Korpela, 2012, p. 293). In the World War II special saunas were built to remove parasites from the war horses (Ojala 1997, Korpela 2012 p. 293). Today, some horse trainers use sauna as part of their training system, in order to make recovery from training more efficient. Trainers have noticed some benefits from taking horses to sauna, including less respiratory diseases and faster post-exercise recovery. (Tarvainen, 2017, personal communication)

Trotters are trained equine athletes. To compete and train successfully and without major physical traumas, horses must be physically healthy. Balanced musculoskeletal system prevents traumas and improves performance of sport horses. For example, in race horses the weakness of back muscles leads to overuse of hind limb muscles. That can cause hind limb injuries and pain. (Wolf, 2002)

This thesis focuses on sauna bathing's effects to equine muscle tone characteristics. Hypothesis was that sauna bathing would relax the horses' muscles. That would be seen as reduced muscle tone and dynamic stiffness after sauna bathing compared with the status before going to sauna.

The author's personal experience is that sauna bathing is mentally and physically relaxing. Muscles seem to recover faster from training if sauna has been visited after working out. Mental aspect of sauna bathing has been studied in human medicine, but this would be hard to assess in horses.

This was the first time the effects of sauna bathing in horses were studied.

## **ACKNOWLEDGMENTS**

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# 1. LITERATURE REVIEW

## 1.1 Human medicinal studies on physiological effects of sauna

Numerous studies have been made in human medicine that are associated with sauna. PubMed's search gives 791 results when the word "sauna" is either in title or abstract (PubMed, 9.4.2018).

129 results are found when "exercise" is added to search conditions. 118 results appear when "sauna" is combined with "cardiovascular". Sauna is found to increase heart rate (Lammintausta *et al.* 1976, Leppäluoto *et al.* 1986), but in repeated sauna bathing there is some adaptation (Leppäluoto *et al.* 1986). It is unknown whether tachycardia is due to decreasing parasympathetic activity or increasing sympathetic activity (Leicht *et al.* 2018). Post-exercise sauna bathing improved endurance runners' performance possibly by increasing blood volume (Scoon *et al.* 2007). Sauna bathing combined with exercising was found to improve cardiac function in patients with chronic heart failure (Haseba *et al.* 2016).

Taking dry sauna baths is a component of Waon therapy that is used in patients with chronic heart failure. Patients go to dry sauna and are then wrapped inside warm blankets. In Sobajima's study (2005) Waon therapy was performed daily for 3 weeks. Flow-mediated vasodilation (FMD) was monitored before and after Waon therapy. FMD increased from 3.6 to 5.1 % during test period. Exercise tolerance was measured within 6 minutes walking test and it increased from 323 to 366 meters. Patients' quality of life improved according to test group's self-assessment using SF-36 method. This method takes into account 8 parameters of patient's physical and mental health including body pain and social functioning. (Sobajima *et al.* 2015)

Sauna bathing reduces systolic and diastolic blood pressure (Laukkanen *et al.* 2018) which can be the reason behind reduced risks of cardiovascular diseases (Laukkanen *et al.* 2018, Zaccardi *et al.* 2017). However, in a study where sauna temperature was 110 °C, increase in blood pressure was detected (Pasek *et al.* 2016). Other studies were done in lower temperatures.

It is suggested that regular sauna bathing at least twice a week may reduce the risk of developing acute and chronic pulmonary diseases (Kunutsor *et al.* 2017). Lung function parameters forced vital capacity and forced expiratory volume were improved in patients with obstructive



pulmonary disease and sauna was not considered a health risk for them (Cox *et al.* 1989). Irreversible microscopic damages to epithelial cells in airways have been detected (Laitinen *et al.* 1988).

Prophylactic sauna bathing was found to improve muscle functions in wrist extensor muscle (Khamwong *et al.* 2015). Heat stress was found to reduce the muscle endurance in weight-trained men in leg-press and bench press. Sauna did not have effect on one repetition maximum (1RM) bench press but had a significant reduce in 1RM leg-press. Therefore, effects to strength were unclear. Muscular power was increased after sauna when measuring vertical jump. (Hedley *et al.* 2002).

It has been suggested that incidence of common colds is less frequent with regular sauna bathing. In one study, the severity and duration of colds was found to be similar to the control group. (Ernst *et al.* 1990) Inhaling dry hot air in sauna did not affect the severity of common cold symptoms (Pach *et al.* 2010).

It has been discussed that hyperthermia (body temperature  $>39,0^{\circ}\text{C}$ ) in the first trimester of pregnancy could be teratogenic to the embryo. In a study it was found that it was unbearable to stay in the sauna until body temperature reached the critical level. Therefore, women are usually unable to be in sauna long enough to reach the harmful body temperature. (Harvey *et al.* 1981) It has been studied that healthy women can go to sauna throughout the pregnancy without negative effects to the embryo (Wähä-Eskeli *et al.* 1988).

Frequent sauna bathing was found to be inversely related with lower risks of developing memory diseases and Alzheimer's disease, though the potential mechanisms are still unknown (Laukkanen *et al.* 2017). Sauna bathing is found to be beneficial in reducing weight and increasing insulin sensitivity, which can be used in treating patients with type 2 diabetes (Krause *et al.* 2015). It has also been studied that quality of life within type 2 diabetes patients may be improved (Beever 2010).

Sauna bathing was also found beneficial in reducing symptoms caused by metamphetamine addiction (Ross & Sternquist, 2012).

## **1.2. Experiments with animals on effects of sauna bathing**

Sauna in veterinary medicine has not been a common object of research. No studies were found that included horses. A few studies have been made with rats and hamsters, and most of them have cardiovascular aspect. That may be due to the aim to study questions relevant to human medicine using animals. Temperature of sauna where rodents were taken was usually below 40 °C.

In hamsters it has been found that regular sauna bathing helps to maintain arterial endothelial nitric oxide synthase levels in sufficient levels (Ikeda *et al.* 2001). Endothelial nitric oxide synthase has effect in arteriolar smooth muscle cells and leads to hypotension by causing arteriolar dilatation (Sjaastad *et al.* 2016, p. 481).

Repeated sauna therapy was found to improve coronary vascularity in rats with myocardial ischemia (Sobajima *et al.* 2001).

## **1.3. Sweating**

Sauna bathing causes increased sweating. Sweat glands are regulated by sympathetic nervous system. Sweat consists of water, electrolytes and other substances such as urea and lactic acid. (Sjaastad *et al.* 2016, p. 763) In a study performed in rugby players a positive correlation was found between sweat rate and lactate concentration in sweat. There was no difference in concentration of lactate between exercise and sauna induced sweating. Lactate concentration in blood did not correlate with concentration in sweat. That is believed to occur because hyperlactatemia is caused by anaerobic metabolism and lactate in sweat is excreted independently of oxygen supplies. (Alvear-Ordenes I *et al.* 2005; cited in Derbyshire *et al.* 2012)

Horses have a large number of sweat glands and for them, sweating is an efficient way of thermoregulation. Trained, euhydrated horses can produce sweat at the rate of 10 to 15 liters per hour over several hours. Dogs, cats and pigs have a low density of sweat glands. (Sjaastad *et al.* 2016. P. 764-765) Other thermoregulatory methods (radiation, conduction and convection) are inhibited when environmental temperature is higher than body temperature

(Sjaastad *et al.* 2016, p. 778). Taking these animals to sauna might lead to excessive heat stress and hyperthermia due to limited sweating ability.

## **1.4 MyotonPRO**

The MyotonPRO Digital Palpation Device (MyotonPRO, Myoton Ltd, Estonia) is a myotonometric device that is developed for human medicine and physiotherapy. It has been used mainly in human medicine but also some animal experiments are published. The author did not find any published studies in horses.

Measuring is non-invasive and can be performed in vivo. It has been considered reliable and valid device in measuring muscle stiffness in humans, although it does not seem to replace algorithmic measuring (Davidson *et al.* 2012, Zinder *et al.* 2011). The results of the measurements are quantitative. It can also be reliably used in evaluating tendon characteristics (Sohirad *et al.* 2017).

MyotonPRO was used in dementic patients with paratonia. The best agreement characteristics were tone, elasticity, and stiffness. Results were more reliable cross-sectionally but among paratonic patients there was a lot of variation. That might also be due to nature of paratonia, but additional guidelines should be researched to increase the clinical interpretation in myometric results. (Drenth *et al.* 2017)

After eccentric exercise in trapezius muscle myometric results in muscle belly and musculotendinous sites were opposite. Measurement results were reliable. (Kawczyński *et al.* 2018)

MyotonPRO has been used for example in patients that have Parkinson's disease (Marusiak *et al.* 2012). It can be used in investigation of myopathies. In rats, dexamethasone-induced muscle atrophy was studied. The rats were anesthetized with combination of ketamine and xylazine to perform measuring with Myoton. Older rats were more susceptible to dexamethasone-induced muscle atrophy and myotonometric measurements were used for evaluation of changes in muscle tissue. (Alev *et al.* 2018)

## 2. MATERIALS AND METHODS

### 2.1. Test group

Test group consisted of five individual horses belonging to two different breeds (Finnhorse and Standardbred). The age of studied horses varied from 5 to 9 years. The median age was 5 years (Table 1).

All horses in test group were physically healthy. Their body condition score was 3/5 in scale of 1 to 5. All horses were trotters who had been regularly trained. The heart and respiratory sounds of all studied animals were auscultated before the start of the experiment and no abnormalities were detected, except for one individual (ID 3 in table 1) that had a history of lung disease and its respiratory sounds were exaggerated. Clinical symptoms in horse ID 3 were not acute.

The interval from previous exercise and the first measuring before sauna ( $T_0$ ) varied from 15 minutes to 24 hours. The trainer decided which horse would go to sauna and it depended on for example upcoming races. Intensity of exercise varied from light to heavy. Walking or slow speed trotting up to 1 hour was considered light exercise. Medium exercise included medium speed trotting or longer duration than in light work. Exercise was considered heavy when training included high speed trotting, competing or swimming.

**Table 1.** The test group individuals

ID	Sex	Breed	Age (years)
1	Stallion	Finnhorse	9
2	Stallion	Finnhorse	5
3	Gelding	Standardbred	5
4	Gelding	Standardbred	5
5	Mare	Standardbred	5

## 2.2. Control group

The control group consisted of four horses. Horses in that group had never been to sauna. They represented 3 breeds: a Finnhorse, a warmblood and two Standardbreds. Age varied from 3 to 7 years (Table 2).

All horses in control group were healthy and their body condition score was 3/5 in scale of 1 to 5. The heart and respiratory sounds of all control group animals were auscultated before the start of the experiment and no abnormalities were detected. Finnhorse and standardbreds are trotters that are regularly trained. Warmblood is a riding horse that is used for dressage and showjumping in amateur level and its training intensity is low.

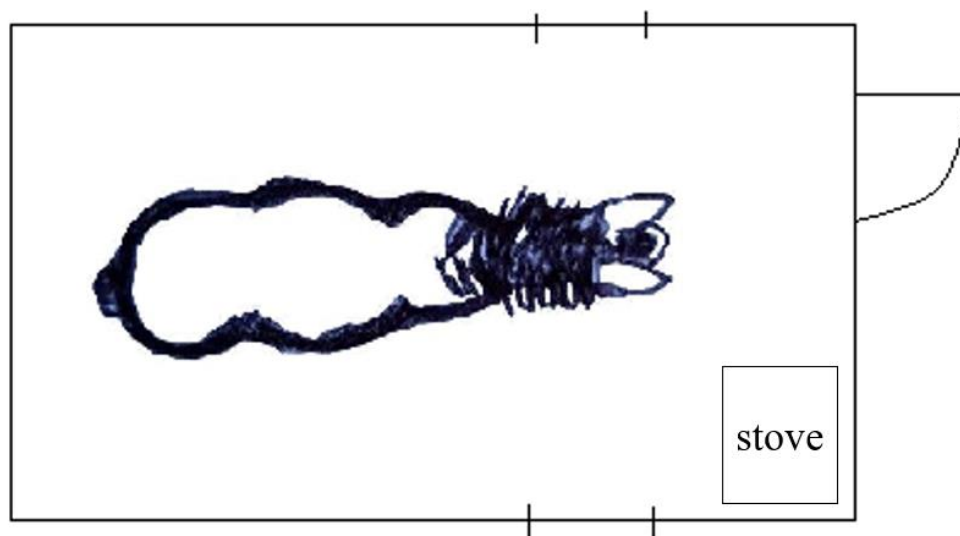
The interval from previous exercise and  $T_0$  varied from 1 to 24 hours. Intensity of exercise varied from light to medium. Categorization was the same as in test group.

**Table 2.** The control group horses

ID	Sex	Breed	Age (years)
1	Gelding	Warmblood	7
2	Mare	Finnhorse	6
3	Mare	Standardbred	4
4	Mare	Standardbred	3

## 2.3. Sauna

The sauna used in this study is designed and built especially for horses. It is located in central Finland, Saarijärvi, and was built in 1996. The measurements of the steam-room are following: width 2.0 m, length 3.4 m and height 2.3 m (Fig. 1). The seats are absent. It is mainly used for one horse at a time, but two horses can also be placed in the sauna at the same time. The sauna stove (Harvia, Finland) is electrical and has power of 9 kW.



**Figure 1.** Outline of the steam room. There are two windows, a door and a stove in the corner. During sauna bathing horse is placed in a position seen in the picture.

During measurements the temperature in sauna varied from 50 to 60 °C. Relative humidity varied from 80 to 100% and it was maintained by regularly adding water to stones used in stove.

The sauna has two windows, one opening to the stable and the other one outside (Fig. 1). During measuring the windows were closed except for the time water was added to stove.

## 2.4. MyotonPRO

The MyotonPRO (Myoton Ltd, Estonia) has a small probe which touches the skin with high speed and certain force. That makes the underlying tissues oscillate and the device collects the impulse it gets back. (Myoton, 2018)

MyotonPRO collects 5 different muscle tone and elasticity characteristics during each measurement. (1) Oscillation frequency [Hz] is a character of muscle tone while muscle is relaxed. When muscle is contracted, oscillation frequency characterizes tension. (2) Dynamic stiffness [Nm] is calculated by the acceleration of the oscillation from the muscle. It expresses how the muscle resists the force which tries to deform it. (3) Logarithmic decrement describes

the muscle's ability to recover its shape after being deformed. Elasticity can then be calculated, and it is inversely proportional to decrement. (4) Relaxation time [ms] is the time when the muscle reaches its original shape. (5) Creep is characterized by ratio of deformation and relaxation time. (Myoton, 2018)

In this study muscle tone characteristics stiffness and frequency are analyzed. Left and right side are analyzed together. MultiScan pattern of 5 measurements with 0,4 seconds interval was performed and the average was calculated.

## **2.5. Measuring points in the muscles**

Muscles selected for this research are all superficial and can be palpable. The measuring point was visualized by clipping hair from the area. The placement of MyotonPRO was perpendicular to the skin above the underlying muscle. During measuring the test horses and control group horses were in neutral standing position, limbs as symmetrically as possible. The aim was to have the muscles as relaxed as possible during every measuring.

### **2.5.1 *M. triceps brachii*, long head**

*M. triceps brachii* has a function of extending the elbow and it has a role in flexing the humeral joint (Ernits & Nahkur, 2013). The measuring point was estimated to be in the middle of long head dorsoventrally and craniocaudally.

### **2.5.2. *M. thoracis longi***

*M. thoracis longi* is located in horse's back. The measuring point was approximately 15 cm caudally from the withers, in the deepest part of the back. Dorsoventrally measuring point was in the middle of the muscle.

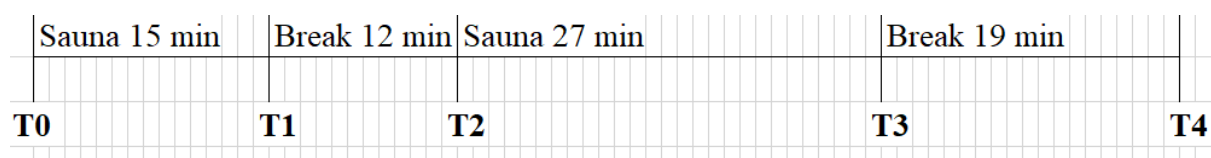
### 2.5.3. *M. semitendinosus*

*M. semitendinosus* is located on the horse's hind limb. Its function when the leg is bearing weight is to extend hip, stifle and tarsus. When non-weight bearing, it has the function of extending the hip and flexing the stifle. (Ernits & Nahkur, 2013) The measuring point was located approximately 15 cm distally from tuber ischiadicum, lateromedially in the middle of the muscle.

## 2.6. Measuring

At first test the training data of previous 24 hours was documented. Heart and respiratory rates were measured immediately prior to the first myotonometric measurement by MyotonPRO ( $T_0$ ). Three muscles were measured bilaterally. After taking the measurements, the horse was led into the sauna. Temperature varied from 50 to 55 °C and relative humidity from 90 to 95 %. The duration of first sauna period varied from 10 to 20 minutes (mode and median 15 min).

Immediately after first period in sauna the clinical and myotonometric exams were repeated ( $T_1$ ). Then horses were given time to cool down. Time of cooling down varied from 10 to 15 minutes (average 12 min). Then each horse was taken to sauna for the second time. Duration of the second sauna period varied from 25 to 30 minutes (average 27 min). Temperature varied from 55 to 60 °C and relative humidity from 80 to 100 %. Instantly after the second sauna period clinical and myotonometric examination were repeated ( $T_3$ ). After that the horse was allowed to cool down for an average of 19 minutes and fourth myotonometric exam was performed ( $T_4$ ).



**Figure 2.** Scheme of measurements. Each square represents a period of 1 minute. All times are presented as approximate.





**Figure 3.** Measuring with MyotonPRO (Photo: YLE, 2017)

Clinical examination was performed in the horses in control group. The data of previous 24 hours of training was documented. After that the myotonometric measurement was performed by MyotonPRO ( $T_0$ ). Myotonometric examination was repeated in average after 50 minutes ( $T_1$ ). Minimum interval was 19 minutes and maximum 75 minutes. The third measuring was performed in average 31 minutes after the second one ( $T_2$ ). Minimum interval was 10 minutes and maximum 48 minutes.

Ad libitum drinking water was offered to test horses before, during and after sauna bathing.

## 2.7. Statistical analysis

The analysed muscle tone characteristics were frequency and dynamic stiffness. Heart and respiratory rates were also analysed statistically. Each muscle was taken separately to analysis and the average values of left and right side were analysed. When the horse had numerous measurements, the mean results were used.

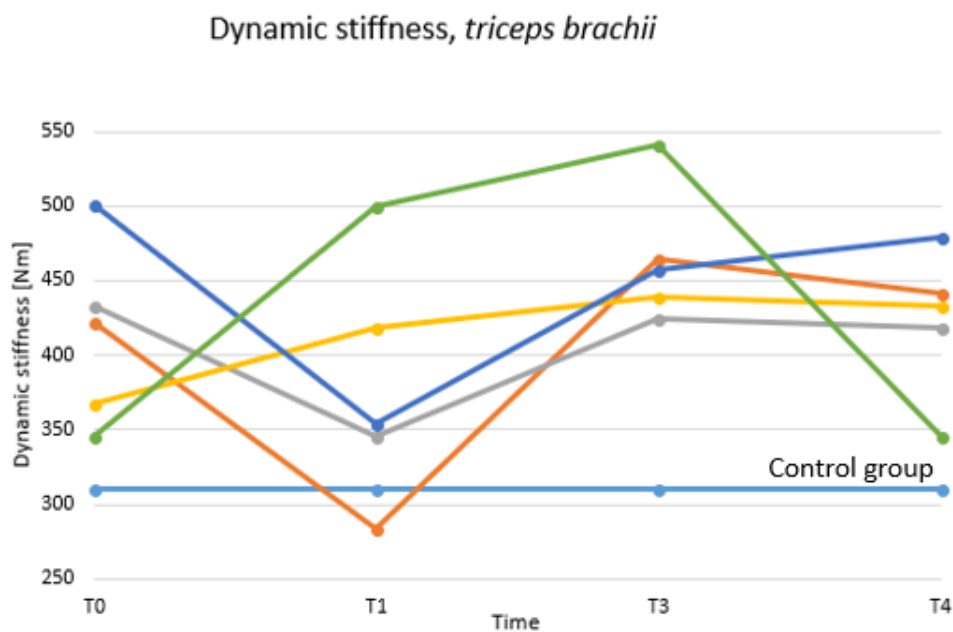
Non-parametric Wilcoxon rank-sum test was used to compare test group's results from T<sub>0</sub> to T<sub>4</sub> with control group's T<sub>0</sub> values.

Non-parametric Wilcoxon matched-pairs signed-rank test was used to compare test group's results in T<sub>0</sub> with T<sub>1</sub>, T<sub>3</sub> and T<sub>4</sub> results.

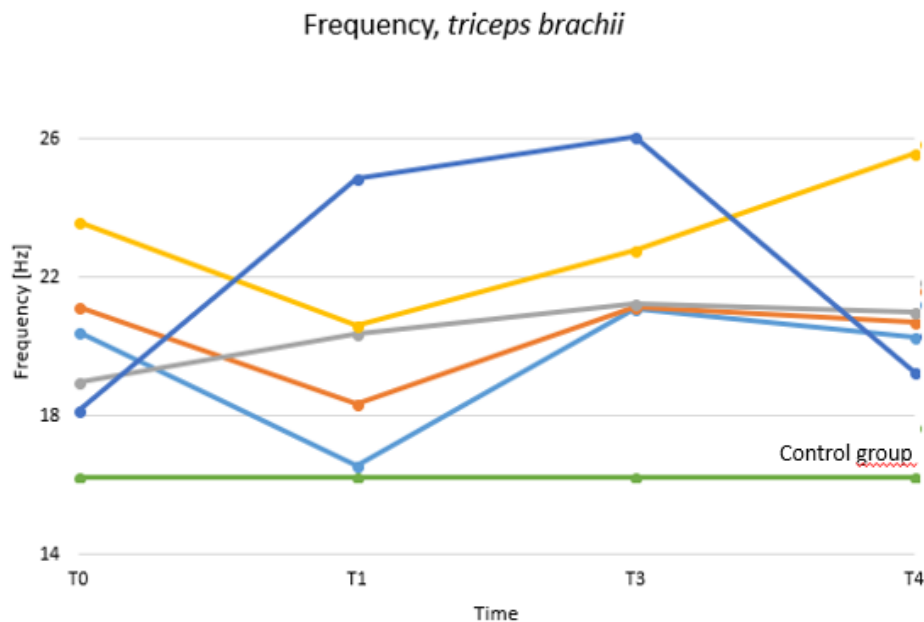
Statistical data analysis was done using STATA 14.0 program (StataCorp LP, College Station, USA). Data management was done using MS Excel 2016 (Microsoft, USA). The level of a significant result was  $P \leq 0.05$ .

## 2.8. Results

In *triceps brachii* no significant differences in dynamic stiffness or frequency were detected between test group and control group (Figure 4, Figure 5). Analysis within the test group also showed no differences.

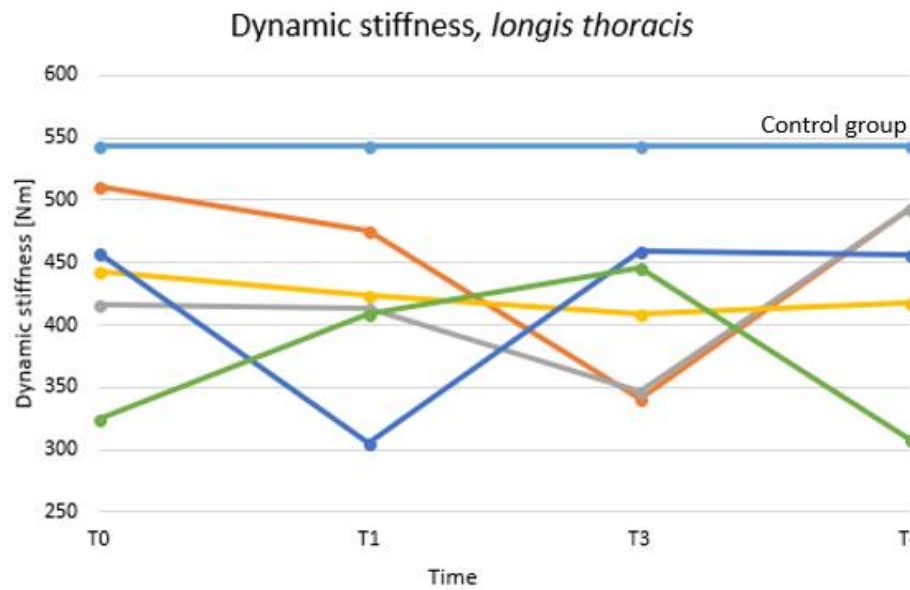


**Figure 4.** Dynamic stiffness of *triceps brachii* during sauna bathing. Each line represents one test group individual. The control group line represents the mean value of all control group horses.

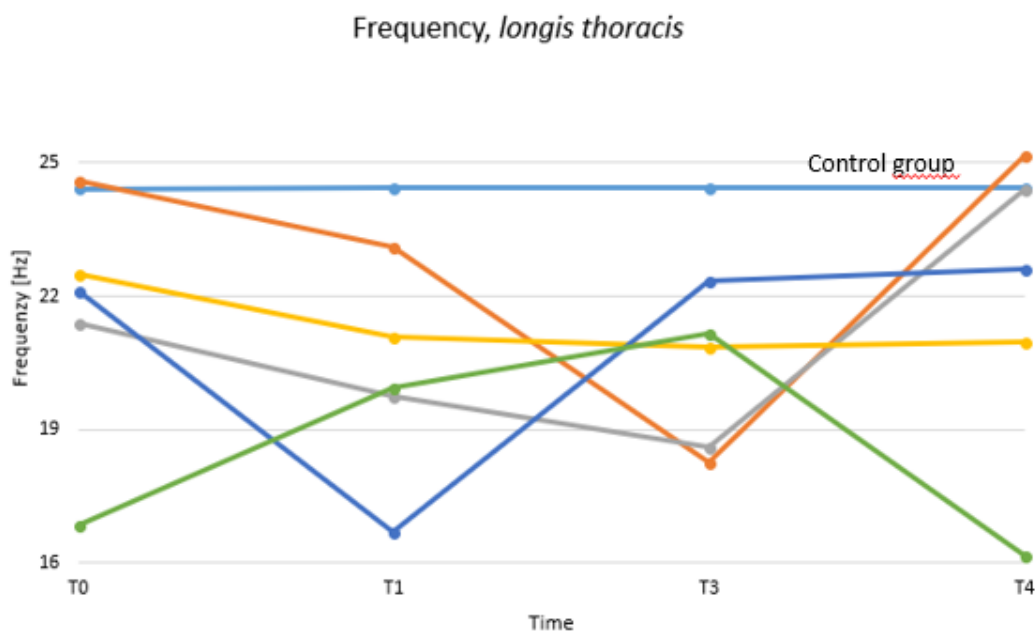


**Figure 5.** Frequency of *triceps brachii* during sauna bathing. Each line represents one test group individual. The control group line represents the mean value of all control group horses.

In test group the frequency of *longis thoracis* was lower than in control group during all 4 measure moments ( $P = 0.05$ ). Dynamic stiffness showed the same trend. Test group had lower dynamic stiffness in *longis thoracis* compared with control group between T<sub>0</sub> and T<sub>4</sub>, but the difference is not statistically significant ( $P = 0.08$ ) (Figure 6, Figure 7).

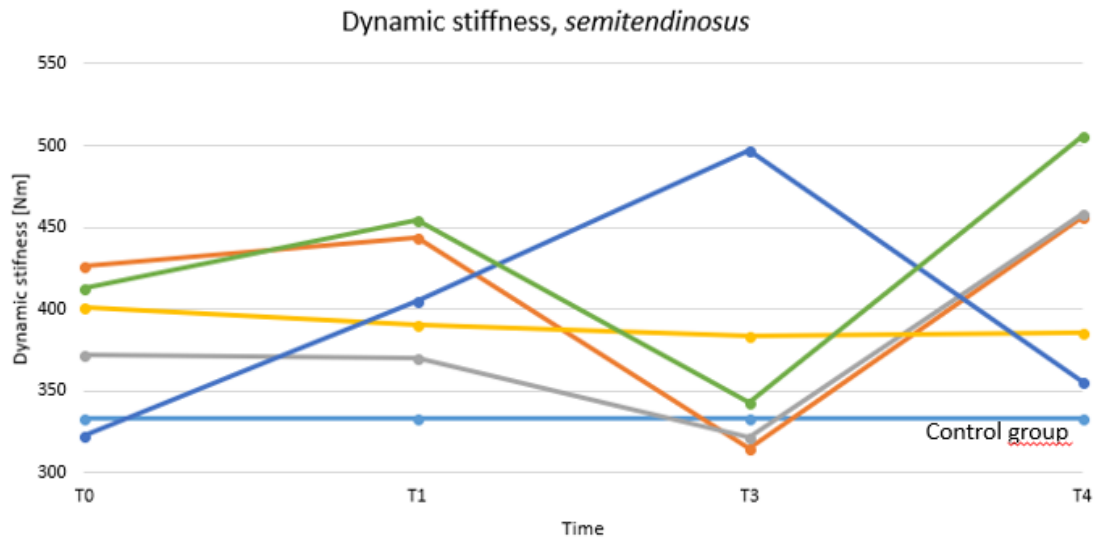


**Figure 6.** Dynamic stiffness of *longis thoracis* during sauna bathing. Each line represents one test group individual. The control group line represents the mean value of all control group horses.

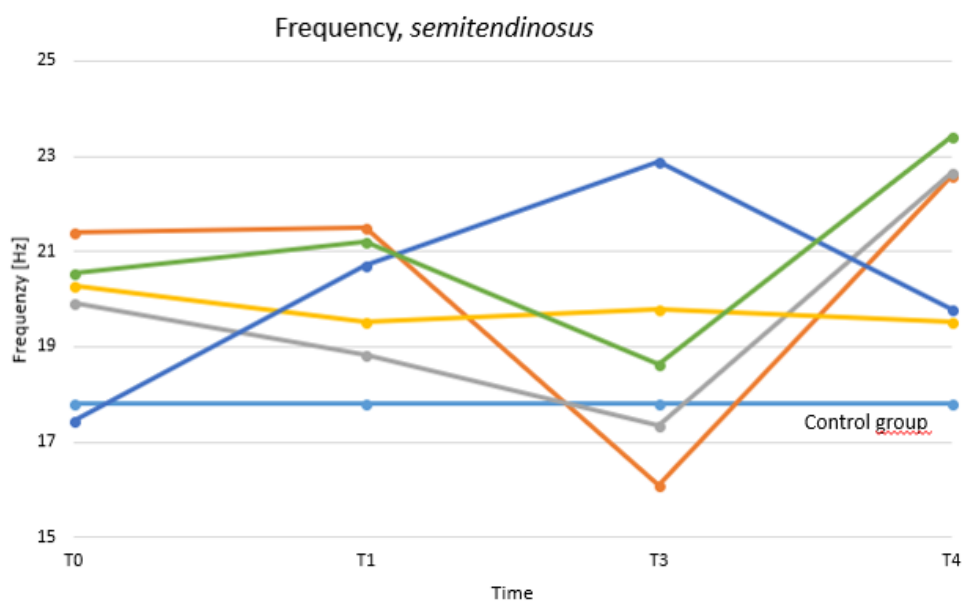


**Figure 7.** Frequency of *longis thoracis* during sauna bathing. Each line represents one test group individual. The control group line represents the mean value of all control group horses.

In *semitendinosus* no significant differences were detected between test group and control group (Figure 8, Figure 9). Analysis within the test group also showed no differences.

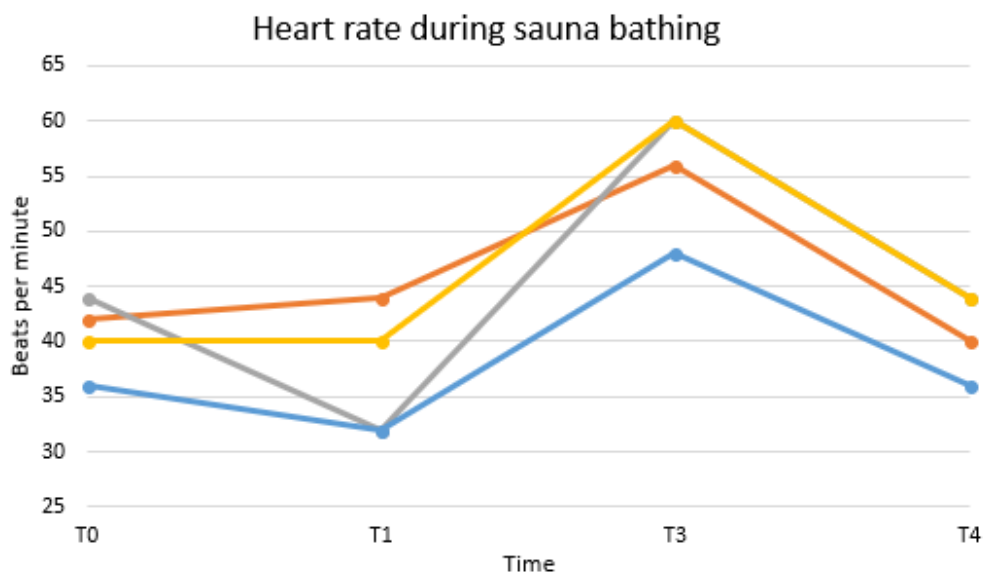


**Figure 8.** Dynamic stiffness of *semitendinosus* during sauna bathing. Each line represents one test group individual. The control group line represents the mean value of all control group horses.



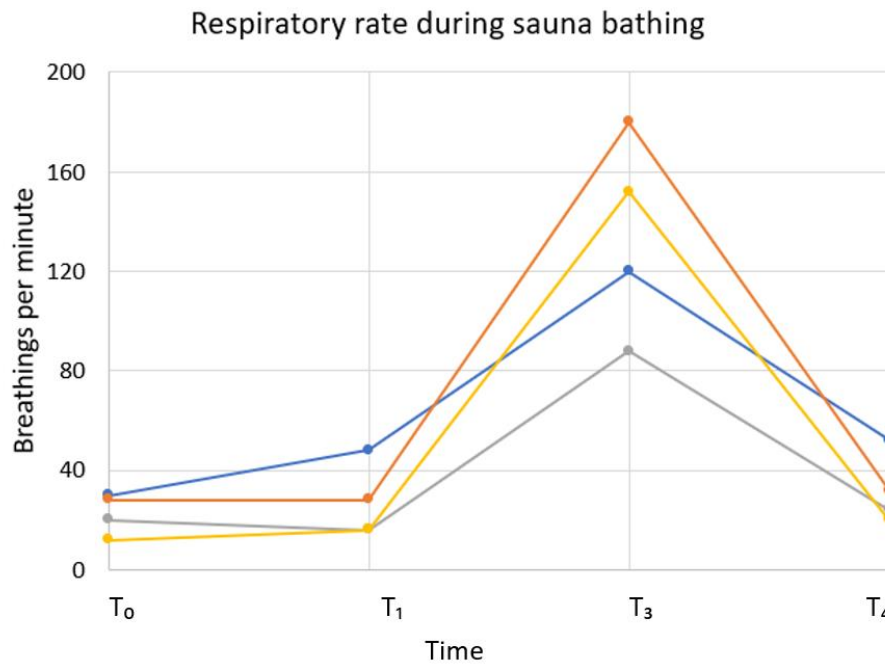
**Figure 9.** Frequency of *semitendinosus* during sauna bathing. Each line represents one test group individual. The control group line represents the mean value of all control group horses.

Heart rate results showed no statistical differences. In all test horses heart rate at T<sub>3</sub> was higher than at T<sub>0</sub>, but this was not statistically significant ( $P = 0.067$ ) (Figure 10).



**Figure 10.** Heart rate during sauna bathing. Each line represents one test group individual.

All test group horses had elevated respiratory rate in T<sub>3</sub> compared with control group ( $P = 0.059$ ) (Figure 11). Test group's respiratory rate was higher in all 4 measured horses in T<sub>3</sub> compared with T<sub>0</sub> ( $P = 0.068$ ). Results are not statistically significant due to small number of measurements. 1 individual did not have statistics about heart and respiratory rates during sauna bathing.



**Figure 11.** Respiratory rate during sauna bathing. Each line represents one test group individual.

### **3. DISCUSSION**

#### **3.1. Major findings and their relevance**

Hypothesis was that sauna bathing would affect recovery of the muscles. That would be seen by reduced tone and stiffness in the muscles. Tone in *longis thoracis* was lower in test group compared with control group. Dynamic stiffness showed the same trend. However, sauna did not affect that difference. Due to relatively small test group, it cannot be known certainly what the reason behind that is. It can only be speculated that the test group horses may have lower tone and stiffness in *longis thoracis* due to regular sauna bathing. High tone in *longis thoracis* is unwanted because it may tell about spasm that is result of chronic irritation and may lead to shortened muscle fiber length and restriction of function (Wolf, 2002).

Visual inspection showed that all test horses had increased sweating. Skin sensitivity seemed to increase as the measuring proceeded. This was detected as skin vibration.

All horses had elevated respiratory and heart rates after second period in sauna. The author suggests that elevated respiratory rate was secondary due to metabolic acidosis. Acidosis is defined as exceed amount of  $H^+$  in the organism. That stimulates ventilation, which is a method of restoring the acid-base balance in the organism. (Sjaastad *et al.* 2016. P. 619)

All test group horses were trained trotters. Last training was  $\leq 24$  h ago and its intensity varied from light to heavy. Causes of metabolic acidosis include accumulation of lactic acid due to anaerobic exercise (Sjaastad *et al.* 2016. P. 624).

#### **3.2. MyotonPRO**

MyotonPRO is relatively reliable in human medicine (Zinder *et al.* 2011). There is only limited experience on using it in equine medicine. Horses have significantly larger muscles than humans and there might also be more connective tissue between the sensor and muscle itself. Non-anesthetized animals may not have completely relaxed muscles. In humans, relaxation of muscles is often achieved by recumbency, but this is not feasible in horses that are not under



sedation or general anesthesia. In order to use MyotonPRO more reliably in horses, basic studying would be needed to detect the best method of performing the measurements.

### **3.3. Environment**

The sauna in this research was located so that it was not isolated from stimuli from the surrounding stable. To improve reliability of measurements, the sauna could be located further away from the stable to exclude the factor of distracting stimuli.

One of the 5 horses in test group did not permanently live in the stable where measuring was made. Transportation is found to increase stress reaction, which may lead to higher sympathetic activity (Ishizaka *et al.* 2017). This might affect the overall tension.

### **3.4. Sex and breed**

Test group horses represented different sexes (2 stallions, 2 geldings, 1 mare). Stallions are more susceptible to a mare's smell than geldings, so individually they are more susceptible to stimuli coming from outside the research area.

2 (40 %) of the test horses were standardbred horses. Their skin appeared to be more sensitive to MyotonPRO according to visual inspection. Their subcutaneous muscles started vibrating when the probe touched their skin. This may or may not have influenced the myotonometric results.

The capacities of Finnhorse and Standardbred's vary for example in top trotting speed. The fastest Standardbred was 8,8 seconds faster in 1600 metre race compared to the fastest Finnhorse (Suomen Hippos, 2018). Therefore, they cannot be trained identically and differences in training may not lead to similar musculature.

### 3.5. Investigated muscles

During measurements the aim was to keep horses in neutral standing position according to their own anatomical characteristics. However, smaller movements may have gone unnoticed, so the pose may not have been identical during each measuring. Slight changes in positioning may have influenced the results of MyotonPRO.

Front leg being caudal to its neutral position causes the muscle tone characteristics in *triceps brachii* to be higher. The different postures of hind limbs caused variation in myotonometric results within *semitendinosus* muscle.

Movement of horse's head and neck influenced muscle tone characteristics in *longis thoracis*. The aim was to hold the neutral position of head and neck.

After the second period in sauna all test horses had elevated respiratory rate which caused cranio-caudal movement of the whole body. When measuring *m. semitendinosus*, the sensor of MyotonPRO was parallel with the movement which may have caused some variability in results. Sometimes the cranio-caudal movement was so remarkable that it was impossible to perform T<sub>3</sub> measuring immediately after sauna. In that case approximately 5 minutes break was given. Cranio-caudal movement became less pronounced within 5 minutes and T<sub>3</sub> measurement could be performed.

### 3.6. Other strengths and limitations of the study

Test group was relatively small (n=5) and heterogenous. Because of small test group size all data could not be utilized due to restrictions of statistical analysis. For example, the effect of previous training was left out from statistical analysis. One test horse lacked data about heart and respiratory rates in sauna. Even though all test horses had elevated respiratory rate in T<sub>3</sub> compared with T<sub>0</sub>, the results were not statistically significant due to small number of test horses.

To make measurements more reliable and repetitive, interval from training to sauna bathing and measuring should be standardized. That would enable to detect the possible effects of sauna bathing in different phases of recovering.

### **3.7. Further research**

Further research is needed to evaluate the possibility of metabolic acidosis. This could be done by evaluating venous blood gases. Due to few number of studies, some basic parameters could be studied among horses during sauna bathing, including blood profiles and extended clinical examinations. The study described in this thesis could be also studied using bigger test group and making test group more homogenous.

## 4. CONCLUSIONS

In this study we did not find significant difference within muscle tone or stiffness before and after sauna bathing. However, it was found that in test group the tone of *longis thoracis* was lower than in control group. Respiratory and heart rates were elevated in all test horses after second period in sauna. Measuring horses with MyotonPRO would need some optimizing to improve the quality of results.

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## APPENDICES

Appendix 1. Non-exclusive licence for depositing the final thesis and opening it for the public and the supervisors' confirmation for allowing the thesis for the defence

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1. grant Eesti Maaülikool, the Estonian University of Life Sciences, a free-of-charge non-exclusive licence to store the final thesis titled Effect of Finnish sauna to equine muscle tone based on MyotonPRO measurements, supervised by Reet Herm and Arvo Viltrop for
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